

MELON APHID RESISTANCE IN CUCURBITS

By

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MELON APHID RESISTANCE IN CUCURBITS

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Cucurbit seedlings were screened in the laboratory to discover plant introductions (PI's) from USDA New Crops Division and cultivars for use in breeding crops resistant to the melon aphid Aphis gossypii Glov. Citrullus sp. PI 296355, Citrullus lanatus (Mansf.) PI 299335, Cucumis anguria L. PI 147065, and Cucumis melo L. PI 164320 and U. S. Horticultural Field Station line LJ 90234 were resistant both in the laboratory and in subsequent field tests at Gainesville, Florida. Cucumis metuliferus Naud. PI 292190 and PI 202681 were highly resistant in the laboratory. Several other species of Cucumis introductions were resistant in the screenings but have not been tested further. Luffa cylindrica (L) PI 249640 seemed to be promising for melon aphid resistance. Cucumis sativus L, Luffa acutangula Roxb., Lagenaria siceraria (Mol.), and 6 species of Cucurbita were examined with inconclusive results. 'Snake Gourd' Trichosanthes sp. had resistant leaves but susceptible cotyledons, a phenomenon not observed in any other genus examined.

Both alate and apterous melon aphids congregated on plants of Cucumis melo, varieties previously found susceptible in terms of survival and reproduction, but not on resistant PI 164320.

Resistance was dominant in crosses of resistant PI 164320 with 2 other Cucumis melo lines. Subsequent generations showed segregation resembling that observed in situations involving a small number of genes. However, attempts to fit the data to simple Mendelian models failed.

Analysis of varietal performance on the basis of geographic origin revealed 2 possible sources of resistant germ plasm. One, for Citrullus, is (or is a part of) Africa where the variability for melon aphid susceptibility is greater than other regions investigated. Another for Cucumis anguria and its close relatives includes Ethiopia and Arabia, where average resistance is higher than other regions investigated.

INTRODUCTION

The melon aphid, Aphis gossypii Glover, is a pest of cucurbits throughout the milder temperate to tropical world (Anonymous 1968). It may be so abundant on islands that it destroys entire plantings of cucurbits or prevents them from setting fruit (Wolcott 1927, 1955; Zimmerman 1948). Major edible cucurbitaceous crops include watermelon, Citrullus lanatus (Thunb.) Mansf.; cantaloupe, Cucumis melo L.; cucumber, Cucumis sativus L.; gerkin, Cucumis anguria L.; and squashes, Cucurbita pepo L., Cucurbita mixta Pangalo, Cucurbita moschata Poir., Cucurbita maxima Duch., and Cucurbita fecifolia Bouche. In different localities, different squashes are called pumpkins. The dishrag gourds Luffa Adans. and bottle, or white flowered gourds, Lagenaria siceraria (Mol.) Standl., are less important cucurbitaceous crops. This investigation was initiated to discover sources of germ plasm for breeding edible cucurbits resistant to melon aphids, the mode of action of resistance, and how it is inherited. In addition to the above crops many closely related plant species were examined. Both US cultivars and plant introductions (PI's) were examined and will be referred to collectively as "varieties".

REVIEW OF LITERATURE

The literature on Aphis gossypii Glover, the melon aphid or cotton aphid, is perhaps more extensive than for any other aphid except the green peach aphid, Myzus persicae (Sulzer). Only the most pertinent reports are reviewed here. Numerous cases of heavy infestation requiring control were reported in the Cooperative Economic Insect Report. These outbreaks are erratic in distribution except for rather consistent occurrence on cantaloupes in Arizona. Kishaba, Bohn, and Toba (1971) reported heavy natural infestations in California where it was possible to field test cantaloupes for resistance to melon aphid without artificial infestation. Goff and Tissot (1932) reported melon aphid infestations in Florida capable of killing watermelon plants if control measures were not taken. Because of increasingly stringent pesticide regulations there may be an increased demand for aphid resistant cucurbits in the US.

Goff and Tissot (1932) reported 64 hosts for the melon aphid in Florida. They found that melon aphids lived 9 to 64 days including a 2 to 32 day reproductive period. The mean life span was 28.4 days and between 16 and 47 generations were completed each year depending on whether a generation was measured from the last born or from the first born, respectively. Female melon aphids outdoors were not killed by cold weather any time during the years 1921-1932. Only parthenogenetic viviparous, alates and apterae were found. Sexual forms of the melon aphid have not been found in Florida. In Oklahoma, Sanborn (1912) reported that alates and apterae produced about 20 and 80 offspring, respectively. He also

found that melon aphids reproduced as well in warm as in cool weather. He speculated that aphid enemies do not do as well when it is cool and damp, resulting in outbreaks of melon aphids during such weather. Kring (1959) outlined the rather complicated life cycle of melon aphid, including sexual forms and eggs on their primary hosts Catalpa bignonioides Walt and Hibiscus syriacus L. in Connecticut. Melon aphids occur on primary hosts throughout the year. Migrants from primary hosts colonize some cucurbits with difficulty, but do well after establishment and are readily transferred between plants in this family.

Melon aphid colonies on crops are motley. In addition to the alate and apterous adult morphs, the nymphs and apterae range from yellow through green to almost black. Reinhard (1927) found that starvation or crowding of apterae would produce an increase in the number of alates in the following generation. This effect was pronounced only for mothers other than the first generation arising from alates. Local crowding of a small number of aphids produced this effect about as well as crowding on the whole plant. The condition or previous heavy infestation of the plant had little effect on alate production. Dark forms seemed to produce alates more readily. Wall (1933) showed that alates produced the lightest forms which in turn produced a few offspring darker than themselves. Subsequent generations produced increasing proportions of dark forms and increasingly darker forms. The process was accelerated by crowding and forms darker than the first generally produced alates if crowded. The percentage of alates increased as either crowding or the darkness of the mothers increased. Preventing crowding stopped or even slightly reversed progress toward increasing darkness and ultimate alate production.

Virus dissemination is associated with aphid movement, but plant

resistance to aphids is of questionable value for virus control. According to Broadbent (1969), viruses introduced to fields early in the growing season spread as the aphid population grows. However, Lowe and Russel (1969) were concerned that aphids might move about more and spread viruses more quickly between plants resistant due to nonpreference than between susceptible plants.

If plant resistance is even a small restraint to aphid multiplication the effectiveness of natural enemies might be increased considerably (van Emden and Wearing 1965).

Investigation of tolerance to aphids is difficult when working with many varieties as it usually involves prolonged investigations with large numbers of aphids (Painter 1958a). Kennedy and Booth (1951) proposed a "dual discrimination theory" in which aphids discriminate between plants or plant parts in 2 ways. One of these is flavor (including contact and olfactory) discrimination. Flavor (from characteristic secondary plant substances) may be too weak or too strong. Mature leaves may have a stronger flavor than young leaves or very senescent leaves. Less adapted aphid species may tend to colonize the latter 2 age groups while well adapted aphids may more readily accept mature leaves. Another form of discrimination is nutritional. In this case aphids tend to accept immature or senescent leaves. This may be due to food stuffs being mobilized in the phloem (Kennedy 1958, Kennedy and Booth 1951, Kennedy, Ibbotson, and Booth 1950). Nutritional discrimination may be more closely related to growth and fecundity than is flavor discrimination. Selection by aphids and suitability for multiplication are not necessarily caused by the same plant characters according to Radcliffe and Chapman (1965). In their experiments cabbage aphid, Brevicoryne brassicae (L.), alates avoided red cabbage and

tended to land on green varieties even though red varieties were more suitable for cabbage aphid multiplication.

Auclair (1967) found that Aphis gossypii given access to nutrient solutions differing in pH and sucrose tended to feed on the ones most favorable for growth and reproduction. Vavilov (1951) indicated that selection against bitterness, acidity, etc. in breeding food crops may select for insect susceptibility. Painter (1958b) also pointed out the possibility of losing insect resistance in breeding for palatability. Cucurbitacins, the bitter principles of cucurbits, are bred out of fruits so they will be edible by man. In the foliage they are repellent to many insects and suppress the development of twospotted mites, Tetranychus urticae (Koch). On the other hand cucurbitacins attract spotted cucumber beetle, Diabrotica undecimpunctata howardii Barber (Da Costa and Jones 1971, Chambliss and Jones 1966). Vavilov (1951) noted that many plants that are introduced without their native pests are relatively free of insect attack. This implies that characteristic secondary plant substances are broadly toxic or repellent or both. In discussing secondary plant substances, Fraenkel (1959) theorized that insects have adapted to be attracted by plant toxins they can detoxify, thus reducing interspecific competition for food.

Ivanoff (1944, 1945) in Texas reported melon aphid resistance controlled by a single partially dominant gene in varieties of muskmelons of West Indian origin. These varieties were 'Orange Fleshed Rocky Dew', 'Cuban Castillian', and 'Smiths Perfect'. Inheritance of this resistance was associated with resistance to the downy mildew, Pseudoperonospora cubensis (Berk. and Curt.) Rostow.

Kishaba, Bohn, and Toba (1971) reported Cucumis melo LJ 90234 selected

from Indian PI 175111 resistant to melon aphids collected from watermelon in the Imperial Valley of California. LJ 90234 was highly susceptible to western flower thrips, Franklinella occidentalis (Pergande).

For each crop there seems to exist one or more geographic regions in which the variability of that plant is much larger than elsewhere (Vavilov 1951). Knowledge of these centers of variability is very important to plant breeders for new sources of resistance.

Vavilov's (1951) law of homologous series states that closely related species and genera show similarities in series of inherited variations. He draws several examples from cucurbitaceous crops. Homologies arise from common ancestors or similar selective pressures on similar organisms. In many cases (i.e., Drosophila species) the homologous characters are inherited in the same fashion in related species. He assumed that except for a few nonhomologous variations to defining species, related species should have naturally occurring homologs for every variation or at least it should be possible for them to occur by mutation. Thus a plant breeder has a better chance of finding a particular type of resistance if it has already been observed in a species related to the one of interest.

CITRULLUS

Cultivated Citrullus include watermelons and citrons, both of which belong to the species Citrullus lanatus. This species is highly variable as to leaf shape and flowering characteristics. The typical leaf is simple with deep sinuses, but variations range from leaves with entire margins to almost pinnately divided blades. Flowering types include monoecious and andromonoecious. The genus Citrullus was screened primarily for the purpose of obtaining melon aphid resistant breeding stock for the dessert type watermelon, a high intensity US crop.

Materials and Methods

All melon aphids used in these and subsequent tests were descendants of aphids obtained September, 1967 from watermelon and colonized at the University of Florida Agricultural Research Center at Leesburg. Aphid colonies were maintained on cantaloupe.

Citrullus plants grown for screening were germinated in 4 inch plastic pots using a 1:3 mixture of peat and sandy loam. Each seedling at the 3-4 leaf stage was infested with 3 apterous female aphids and covered with a no. 2 lamp chimney capped with fine white organdy. The plants were then placed in a $26 \pm 1^{\circ}$ C room with 16 hr of light daily from cool white fluorescent lamps 45 cm above the pots. The unobstructed light intensity at the soil surface was 220 ft-c. The temperature in the lamp chimneys increased 3° C during the light period. Each variety was represented by 4 seedlings, 1 per pot, in a completely randomized design. After 5 days the number of aphids on each plant was recorded.

Five Citrullus plant introductions were tested in the field at the University of Florida Horticulture Research Unit in 1972. They were direct seeded in Arredondo fine sand fertilized with 1,000 lb/acre 6-8-8 containing 2% FTE 503. Hills contained 3 or 4 plants and were 4 ft apart. Four completely randomized blocks were used. About 2 months after planting the tip of 1 runner on 1 plant per hill was infested with 5 apterous female aphids. The infested tip and first 2 leaves were covered with a fine white organandy bag. After 5 days, the number of aphids in each bag was recorded.

The screening test data were analyzed by the nonparametric Wilcoxon's sum of ranks test applied sequentially (Snedecor and Cochran 1967, Langley 1970). Results from the field test were analyzed by Friedman's test and its multiple comparison extension (Langley 1970).

Analyses of the screening data to determine a center of genetic variability were based upon grouping of the varietal means from Table 1 into 5 regions: Africa, Asia, USSR, Turkey, and the Western Hemisphere (mostly the United States). The means were ranked from lowest (1) to highest (61) and analyzed for differences between their regional medians using Dunn's (1964) multiple comparison of rank sums test. Segal-Tukey ranking was used to transform Dunn's test into a multiple comparison of variabilities test (Bradley 1968).

Levels of significance in these and following data were calculated on the basis of 1 tailed probability (i.e., that variety A could be classified as resistant by chance alone) for screenings and 2 tailed probability (as resistant or susceptible) for all other tests.

Results and Discussion

The 61 varieties screened had varietal mean numbers of aphids from

5.25 for PI 296335 to 43.50 for PI 278041 (Table 1). Seven US commercial watermelon varieties were included in the test as well as PI 290855 which was 'Willis Sweet', and all were intermediate, being neither significantly better than PI 296335, from S. Africa, nor significantly worse than PI 278041 from Turkey.

Three resistant and one susceptible variety from the screening tests plus PI 274035, which was believed highly susceptible on the basis of 3 plants, were tested in the field (Table 2). PI 299563 and PI 296335 were significantly (5% level) more resistant than PI 274035. PI 278041 had a varietal mean very near that of PI 296335, but was statistically intermediate. PI 296335 which was resistant in both tests has a small round bitter fruit. PI 299563, also resistant, is a small white fleshed watermelon C. lanatus "Amakeba" from south of the Jozini Dam, Pangola River, S. Africa (Hyland 1968). Both of these PI's and possibly others might be retested with the goal of eventually transferring this resistance to commercial varieties. However, breeding large, or in the case of PI 296335, high quality watermelons might be expensive and time consuming.

The regional medians were very similar. However, further analyses indicated that the African group was significantly (5% level) more variable in resistance to melon aphid than any other group except the Asian group which was not significantly more variable than any other group.

Harlan (1961) concluded that Vavilov's (1951) more pronounced (primary) centers of genetic variability were the result of introgressive hybridization of the crop with weed forms of the same plant. He observed these weed forms, whatever their origin, always to be present at these primary centers. PI 296335, PI 296337, and PI 296341, all from S. Africa, are unidentified Citrullus sp. as is PI 314655 from the USSR. They

Table 1. Mean number of aphids on individual Citrullus plants 5 days after infestation with 3 apterae.

Variety	Origin	\bar{X}^*	Variety	Origin	\bar{X}^*
PI 174812	India	12.00 abc	PI 306365	Congo	22.75 abc
PI 179876	India	32.75 bc	PI 306366	Congo	13.00 abc
PI 278027	Turkey	24.00 abc	PI 306367	Angola	7.50 ab
PI 278029	Turkey	16.50 abc	PI 306782	Nigeria	30.25 abc
PI 278030	Turkey	42.75 bc	PI 307608	Nigeria	24.35 abc
PI 278031	Turkey	16.50 abc	PI 307609	Nigeria	8.00 ab
PI 278041	Turkey	43.50 c	PI 307748	Philippines	20.50 abc
PI 278043	Turkey	17.00 abc	PI 307749	Philippines	37.00 bc
PI 278044	Turkey	21.25 abc	PI 314148	USSR	24.75 abc
PI 278047	Turkey	17.00 abc	PI 314178	USSR	29.75 abc
PI 278051	Turkey	19.25 abc	PI 314655	USSR	34.25 bc
PI 278052	Turkey	11.25 ab	PI 319212	UAR	30.50 abc
PI 278053	Turkey	18.50 abc	PI 325248	USSR	12.00 ab
PI 278055	Turkey	32.25 bc	PI 331106	Uruguay	28.50 abc
PI 278061	Turkey	28.50 abc	PI 344066	Turkey	23.00 abc
PI 278062	Turkey	27.50 abc	PI 344298	Turkey	18.75 abc
PI 279456	Japan	28.00 abc	PI 344310	Turkey	35.75 bc
PI 279459	Japan	17.75 abc	PI 345543	USSR	10.50 ab
PI 279460	Japan	8.50 ab	PI 345544	USSR	23.25 abc
PI 288232	Egypt	22.00 abc	PI 345545	USSR	25.00 abc
PI 288317	India	32.25 bc	PI 346547	USSR	28.75 abc
PI 288522	India	30.75 bc	PI 346787	Turkey	18.25 abc
PI 290855	USA	25.00 abc	Charleston		
PI 293766	USSR	25.00 abc	Grey	USA	26.75 abc
PI 296334	S. Africa	13.25 abc	Congo	USA	14.50 abc
PI 296335	S. Africa	5.25 a	Dixie		
PI 296337	S. Africa	38.25 bc	Queen	USA	12.75 abc
PI 296339	S. Africa	38.00 bc	Florida		
PI 296341	S. Africa	41.75 bc	Giant	USA	28.50 abc
PI 299379	S. Africa	39.75 bc	Keckly		
PI 299563	S. Africa	6.25 ab	Sweet	USA	16.25 abc
PI 306364	Congo	24.25 abc	Stone		
			Mountain	USA	26.25 abc
			Sugar Baby	USA	26.75 abc

*Varieties followed by the same letter are not significantly different at the 5% level.

Table 2. Number of aphids 5 days after infestation with 5 apterae placed on the tip of a Citrullus runner covered by an organdy bag in the field. 1972.

Variety	Replication				\bar{x}^*
	I	II	III	IV	
PI 274035	6	4	47	41	24.5 b
PI 278041	0	2	5	1	2.0 ab
PI 296335	5	0	0	1	1.5 a
PI 299563	0	3	1	0	1.0 a
PI 345543	14	0	19	13	11.5 ab

* Means followed by the same letter are not significantly different at the 5% level.

all set fruit at Gainesville when pollinated with watermelon pollen and may all be, to some extent, part of the C. lanatus gene pool in their respective areas. Most unidentified Citrullus sp. in the USDA New Crops Division's plant introductions are from S. Africa. Presuming these to be Harlan's weed forms would make possible a primary center of genetic variability in that area. Investigators seeking additional germ plasm for breeding melon aphid resistant watermelons should examine African introductions first. They should also consider the possibility that the variability may be concentrated in some smaller area within Africa, such as S. Africa.

LUFFA AND LAGENARIA

Several genera of cucurbits produce fruits suitable for drying as ornaments. Prominent among these "gourds" are Lagenaria and Luffa. These plants were studied early in this search for melon aphid resistance, both for the improvement of edible forms and for the development of testing techniques. Luffa cylindrica (L.) Roem. and L. acutangula Roxb., the dishrag gourds, are eaten in the Orient as immature fruits. The fibrous placentae of the mature fruit are used for many artifacts and are strategic as a marine oil filtering material. Lagenaria siceraria, the white flowered or bottle gourd, although usually bitter and toxic, includes a few edible varieties which have a single recessive allele suppressing production of the toxic cucurbitacins (Whitaker and Davis 1962).

Materials and Methods

Late first to early second leaf Luffa seedlings were grown, infested with 3 apterae and covered with a lamp chimney for screening, as outlined for Citrullus. A completely randomized design was used outdoors between May 3 and May 12, 1971, at Gainesville, Florida. The plants were shaded except for an hour or two of direct sun in the early morning. Each variety was represented by 4 to 6 seedlings. After 9 days the total number of aphids on each plant was recorded.

First leaf Lagenaria siceraria seedlings were screened as described for Citrullus, but 6 randomized complete blocks were used. After 5 days

the aphids on each plant were recorded.

Field testing was done in 1972 the same way as with Citrullus except that 8 varieties were tested including 4 each of Luffa and Lagenaria siceraria in each of 4 complete blocks.

Varieties in the Luffa screening were placed into significance groups by Dunn's (1964) multiple range test of rank sums applied sequentially and the significance found for each comparison.

Each Lagenaria siceraria variety was compared to the screening population by a sign test comparing individual plants to their replication medians.

Results and Discussion

The number of aphids found on individual plants after 9 days in the Luffa screening ranged from 0 to 24 (Table 3). Group d, the most susceptible, included only varieties upon which aphids increased. All plants of L. acutangula PI 246931 and L. cylindrica PI 249640 and PI 288525 had 0 aphids and were in the most resistant group.

Lagenaria siceraria PI 181913, and PI 181498 were significantly more resistant (5% level) than the test population (Table 4). PI 269507 was highly significantly resistant (1.6% level). Two varieties in the L. siceraria screening, 'Balsam Pear' and 'Queens Pocket Melon', were found to be Momordica charantia L. and Cucumis melo respectively. These were not used to estimate population medians but were compared with them. Almost every L. siceraria variety contained plants that had 0 aphids, but there were none that were all 0's. Genetic variability may have contributed to this overall phenotypic variability. Bailey (1937) felt that there were few, if any, genetically fixed cultivars of Lagenaria.

Table 3. Mean number of aphids on individual Luffa plants 9 days after infestation with 3 apterae.

Variety	\bar{X}^*	
PI 179695	2.80	bcd
PI 183059	5.20	cd
PI 246931	0	a
PI 249640 ^x	0	a
PI 268377	0.50	abc
PI 271362	1.83	abcd
PI 271367	2.75	abcd
PI 271368	1.40	abcd
PI 271480	6.20	d
PI 275635	9.80	d
PI 288515	5.25	d
PI 288516	5.80	d
PI 288517	0.20	ab
PI 288519	4.20	cd
PI 288525 ^x	0	a

*Means followed by the same letter were not significantly different at the 5% level.

^xIndicates L. cylindrica, all others were L. acutangula.

Table 4. Number of aphids on individual *Lagenaria siceraria* plants 5 days after infestation with 3 apterae. Sign of deviation from replication median indicated by + or - following each count.^a

Variety	Replication						Replication					
	I	II	III	IV	V	VI	I	II	III	IV	V	VI
PI 179298	0-	3-	10-	0-	16+	3-	PI 271477	18+	0-	9+	21+	15+
PI 181498	1-	0-	0-	3m	0-	1-r	PI 273663	4+	1-	0-	8+	3-
PI 181913	2-	3-	1-	0-	2-	4m r	PI 273662	0-	4m	6+	16+	4m
PI 188809	5+	1-	4+	0-	0-	0-	PI 280631	2-	10+	11+	7+	20+
PI 195321	21+	4m	3m	7+	14+	8+	PI 280632	1-	0-	7+	0-	8+
PI 197437	2+	17+	11+	13+	8+	2-	PI 280633	1-	4m	5+	14+	5-
PI 256069	0-	0-	0-	0-	16+	1-	PI 280634	1-	72+	4+	0-	4-
PI 269505	1-	5+	0-	2-	5-	0-	PI 280636	10+	19+	3m	8+	2-
PI 269506	7+	3-	10+	0-	8+	0-	PI 287533	2-	0-	0-	1-	0-
PI 269507	0-	0-	1-	0-	5-	0-rr	PI 287534	3+	6+	7+	2-	0-
PI 269508	7+	1-	11+	3m	5-	12+	PI 288497	7+	2-	1-	11+	8+
PI 270456	12+	11+	2-	19+	24+	1-	PI 288499	11+	6+	0-	8+	8+
PI 271351	10+	4m	4+	9+	6-	0-	PI 288500	0-	5+	4+	0-	18+
PI 271353	23+	0-	7+	1-	2-	4m	PI 288501	14+	15+	5+	2-	10+
PI 271354	1-	12+	1-	0-	5-	3-	PI 288503	11+	5+	18+	3m	8+
PI 271356	0-	4m	3m	6+	22+	2-	PI 288506	0-	0-	0-	0-	6+
PI 271357	13+	7+	0-	3m	0-	2-	PI 288508	3+	1-	0-	3m	4-
PI 271358	5+	4m	0-	0-	18+	2-	Zucca Melon	1-	0-	7+	8+	7+
PI 271359	5+	5+	1-	0	11+	4m	Median	2	4	3	3	7
PI 271360	1-	3-	0-	5+	7m	3-	Balsam Pear ^b	0-	0-	0-	0-	0-
							Queens Pocket ^c	21+	8+	37+	35+	47+
							Melon					7+

^a Varietal data followed by r have significantly less +s at the 3% level or rr have significantly less +s at the 1.6% level. Individual counts followed by m are equal to the median.

^b *Momordica charata*.

^c *Cucumis melo*.

The field test included 4 varieties of Lagenaria siceraria, 2 of Luffa acutangula, and 2 of Luffa cylindrica (Table 5). Although the Lagenaria selected for field testing included varieties of high and lesser susceptibility, they were not necessarily the most extreme ones based on the screenings, but were selected for their value in a breeding program. Although the average number of aphids decreased on the Luffa varieties in the field, Luffa acutangula PI 288516 appeared to be the most susceptible of the 4 Luffa in both screening and field tests. Luffa cylindrica PI 249640 had no aphids on any plant at the end of either the screening or the field test. The Lagenaria siceraria data suggested a possible relation between the screening means and field means. Unfortunately the field data were inadequate for statistical significance.

Table 5. Number of aphids 5 days after infestation with 5 apterae placed on the tip of an edible or related gourd runner and covered, along with two leaves, by an organdy bag in the field.

Variety	Block				Field		Screening \bar{X}
	I	II	III	IV	\bar{X}^*	\bar{X}	
	6/23 -6/28	6/24 -6/29	6/29 -7/4	6/30 -7/5			
	<u>Luffa</u>						
PI 246931	<u>L. acutangula</u>	0	1	5	0	2.5	0
PI 249640	<u>L. cylindrica</u>	0	0	0	0	0	0
PI 288516	<u>L. acutangula</u>	4	6	0	1	2.75	5.80
PI 288525	<u>L. cylindrica</u>	0	0	1	1	0.5	0
	<u>Lagenaria siceraria</u>						
PI 181498		0	0	0	0	0	0.83
PI 197437		0	0	1	2	0.75	8.83
PI 280631		1	10	0	9	5	13.33
Zucca Melon		0	0	0	0	0	6.00

*No significance was found.

CUCURBITA

The genus Cucurbita includes the squashes which are a high yielding food crop. The petin gourd, C. lundelliana Bailey, a wild vine with hard bitter fruit is interfertile with most of the commercially important species as are the F_1 hybrids. This general interfertility makes it a possible bridge for transferring characters such as insect resistance between commercial species that do not cross successfully (Whitaker and Davis 1962).

Materials and Methods

Cucurbita pepo L., C. maxima Duch., and C. moschata Poir. were individually screened and analyzed in the same way as described for Lagenaria siceraria. One variety of C. fecifolia Bouche, 1 of C. maxima and 2 of C. mixta Pangalo were included in the C. moschata screening and analysis. Field testing and analyses of results in 1972 were the same as described for Citrullus. The test incorporated 10 varieties, 8 of which were selected from the screenings. Petin gourd, C. lundelliana, and 'Green Striped Cushaw', C. mixta, were also included.

Results and Discussion

'Early Bush Scallop, Green' was significantly more resistant (3% level) than the other entries in the Cucurbita pepo screening (Table 6). PI 212008 and PI 234614 were significantly more susceptible (3% level). There was no indication of resistance in the C. maxima screening (Table 7).

Table 6. Number of aphids on individual Cucurbita pepo plants 5 days after infestation with 3 apterae. Sign of deviation from replication median indicated by + or - following each count.^a

Variety	Replication				
	I	II	III	IV	V
PI 93458	3-	1-	0-	15+	1-
PI 167053	6+	15+	5-	10+	20+
PI 169442	25+	25+	6-	4-	17+
PI 169454	0-	19+	14+	5-	8m
PI 169477	7+	16+	4-	3-	14+
PI 171627	17+	1-	5-	38+	1-
PI 172406	0-	7m	21+	2-	12+
PI 172686	2-	11+	5-	3-	12+
PI 172860	5m	2-	15+	2-	1-
PI 172870	25+	7m	9m	11+	8m
PI 172872	0-	2-	16+	12+	0-
PI 174183	1-	8+	0-	3-	4-
PI 175708	5m	7m	0-	14+	15+
PI 175710	0-	8+	7-	7-	1-
PI 176536	11+	2-	19+	3-	16+
PI 176547	1-	7m	1-	18+	26+
PI 176552	1-	1-	13+	23+	3-
PI 181878	9+	2-	10+	0-	9+
PI 182202	7+	19+	12+	4-	7-
PI 183232	5m	0-	6-	19+	4-
PI 212002	10+	0-	19+	23+	7-
PI 212004	8+	11+	8-	23+	10+
PI 212005	7+	1-	14+	3-	16+
PI 212008	17+	20+	33+	12+	25+s
PI 212060	3-	1-	11+	10+	20+
PI 222247	17+	5-	7-	7-	20+
PI 227237	5m	26+	17+	8m	6-
PI 229688	0-	13+	6-	9+	0-
PI 234614	57+	25+	15+	34+	21+s
PI 266925	7+	7m	25+	26+	27+
PI 267660	1-	0-	3-	11+	0-
PI 288240	12+	2-	29+	6-	5-
Black Zucchini	8+	16+	4-	3-	14+
Early Bush Scallop, Gn.	0-	0-	0-	0-	5-r
Table Queen	3-	10+	13+	0-	3-
Median	5	7	9	8	8

^aVarietal data followed by r have significantly less +'s at the 3% level or s have significantly more +'s at the 3% level. Individual counts followed by m are equal to the median.

Table 7. Number of aphids on individual Cucurbita maxima plants 5 days after infestation with 3 apterae. Sign of deviation from replication median indicated by + or - following each count.^a

Variety	Replication				
	I	II	III	IV	V
PI 165558	0-	25+	5-	18+	2-
PI 169405	3+	2m	6+	0-	2-
PI 194268	11+	1-	0-	7+	4-
PI 265556	0-	19+	20+	21+	2-
PI 265557	0-	10+	3-	1-	11+
PI 302416	0-	0-	1-	4-	7+
PI 318418	1-	1-	0-	7+	6m
PI 318433	2m	2m	10+	6+	17+
PI 325133	2m	16+	9+	2-	6m
Blue Hubbard	2m	1-	17+	0-	3-
Delicious	0-	3+	37+	31+	55+
Hungarian Mammoth	9+	12+	0-	0-	16+
New England Blue Hubbard	9+	1-	1-	5+	2-
True Hubbard	5+	2m	11+	0-	0-
Median	2	2	5.5	4.5	6

^a Varietal data followed by m are equal to the median. No significance was found.

In the C. moschata screening PI 199014 was significantly (3% level) more resistant than the other entries (Table 8). C. mixta PI 314806 was also resistant (3% level) as an entry in the C. moschata screening. The field test seemed to have little relation to the screening results (Table 9). There was no significance for any variety in the field test. Petin gourd and Green Striped Cushaw, which had not been screened, appeared to be susceptible in the field. Although PI 165558 and Green Striped Cushaw had smaller mean numbers of aphids at the end of the test than were applied at the beginning, I suspect that all "resistance" observed in this case was merely random variation. In the case of the significant entries in the screenings, the 1 in 20 chance of erroneous significance (5% level) in so many tests (really 1 per variety) must result in some varieties being misclassified. This great need for confirmation is the reason why the large screenings have not been referred to as tests.

I feel that the screening technique used was adequate for detection of resistance to melon aphid in Citrullus and Cucumis and of little value with Cucurbita which produce highly variable results. Some of the problems observed with Cucurbita seem to involve light intensity. Perhaps PI 314806 had a greater need for light than the varieties with which it was screened (Table 8). Perhaps aphids starve on varieties that do not have enough light.

Table 8. Number of aphids on individual Cucurbita moschata (and C. sp.) plants 5 days after infestation with 3 apterae. Sign of deviation from replication median indicated by + or - following each count.^a

Variety	Replication				
	I	II	III	IV	V
PI 135367	22+	4+	2-	49+	40+
PI 135371	23+	2-	25+	12-	5-
PI 141646	18+	19+	10m	2-	13+
PI 162889	1-	1-	24+	14+	29+
PI 165995	11+	4+	5-	14+	4-
PI 169414	0-	39+	34+	0-	10m
PI 172343	17+	6+	14+	3-	3-
PI 196925	3-	3-	22+	15+	0-
PI 197007	8m	0-	0-	0-	13+
PI 199014	0-	0-	1-	2-	3-r
PI 223842	16+	0-	8-	20+	33+
PI 264551	7-	1-	10m	0-	10m
PI 296388	1-	1-	24+	14+	29+
PI 298036	32+	6+	12+	13-	19+
PI 306125	8m	32+	34+	1-	94+
Butternut	9+	4+	4-	38+	56+
PI 314806	<u>C. mixta</u>	0-	0-	0-	0-r
Buttercup	<u>C. maxima</u>	61+	36+	30+	24+
Delicata	<u>C. mixta</u>	6-	30+	0-	26+
Vegetable					0-
Spaghetti	<u>C. fecifolia</u>	0-	0-	0-	24+
Median	8	3.5	10	13.5	10

^aVarietal data followed by r have significantly less +'s at the 3% level. Individual counts followed by m are equal to the median.

Table 9. Number of aphids 5 days after infestation with 5 apterae placed on the tip of a Cucurbita runner and covered by an organdy bag in the field. 1972.

Variety	Block						\bar{x}^*
	I	II	III	IV	V	VI	
	7/3 -7/8	6/30 -7/5	6/3 -6/8	7/4 -7/9	7/5 -7/10	7/7 -7/12	
PI 93458	1	11	11	5		55	16.60
PI 165558	14	4	0	0	0	1	3.17
PI 199014	20	3	17	5	0	0	7.50
PI 267660	6	7	15	0	1	17	7.67
PI 314806	0	15	5	2	16		7.60
Delicata	20	10	28	28		54	28.00
Early Bush Scallop, Green		36	8	5		18	16.75
Green Striped Cushaw	1	0	12	1	2	4	3.33
Japanese Spaghetti	6	46	37	17	25	4	22.50
Petin Gourd	0	58	17	22	13	51	26.83

*No significance was found.

CUCUMIS

This is a highly variable genus, including very diverse leaf and fruit types and andromonoecious, monoecious, and dioecious flowering habits. The genus is separable into 2 or more major groups. One of these possibly includes Cucumis melo, with 24 chromosomes, and C. sativus, with 14 chromosomes, which have striking homologies despite their different numbers of chromosomes (Whitaker and Davis 1962). Cucumis longipes (Hook. f.) Meeuse is highly interfertile with gerkin, C. anguria L., of which it is now considered to be a wild variety. C. anguria readily crosses with C. dipsaceus Spach., C. africans L.f., C. leptodermus Schweik., C. myriocarpus Naud., C. ficifolius A. Rich., C. prophetarum L., and C. zeyheri Sond., with partial fertility in the F_1 and, in some cases, later generations. The latter 8 species are occasionally referred to as the Cucumis anguria complex (Deakin, Bohn, and Whitaker 1971). All are of interest in breeding gerkins.

Material and Methods

The screening and analysis of Cucumis were in 3 parts. The first 2 parts were whole genus screenings. The third screening included only cantaloupes. The 3 screenings were done and analyzed as described for the Lagenaria screening. The number of aphids was recorded after 5 days for the first and third and after 8 days for the second screening. The first 2 screenings were analyzed together, but as separate samples, to find possible centers of genetic variability in the same way as for

Citrullus. The regions considered in the gene center study were southern Africa, Ethiopia and Arabia, and the Asian subcontinent. The second screening was reanalyzed as a single sample with the United States as a fourth region.

The C. melo part of the C. melo and C. metuliferus test was analyzed by the Friedman's test and its multiple range extension (Langley 1970). The aphids used were produced by putting apterous female melon aphids on Honey Dew plants, waiting 24 hr, removing them, and using the progeny 5 days later when almost all of them were young adults. It was hoped that this procedure might reduce variation. Otherwise the test was done in the same manner as the screenings, and the number of aphids was recorded after 5 days.

In situations such as home gardens and variety trials, where insects may have free choice of varieties, interaction is an important factor (Overman and MacCarter 1972). An accidental infestation provided data in which a group of plants were exposed to melon aphids which had a free choice of plants. This interacting infestation involved a cage, in which were growing 24 completely randomized PI 164320 and Honey Dew 4 to 6 leaf plants, that had a crack through which a few aphids entered. The cage was in the rearing room under the same conditions as the Cucumis screenings, and the plants were growing in tightly packed $1\frac{1}{4} \times 1\frac{1}{4}$ inch square plastic pots. When the infestation was noticed the plants were placed in order from least infested (1) to most infested (24). The resulting positions (ranks) for each variety were recorded. These data were analyzed by Wilcoxon's sum of ranks test (Langley, 1970).

The first apterous preference test was done outdoors in a small cage using second leaf plants in $1\frac{1}{4} \times 1\frac{1}{4}$ inch pots crowded tightly together.

A completely random design was used. Five apterous adult female melon aphids were placed on each plant and the number of adult aphids on each plant recorded after 3 days. Their progeny were not recorded and were still small enough so that no confusion occurred. Zeros were considered the event of interest and the data were analyzed by a binomial test adapted from tables by Burstein (1971).

A large C. melo preference test used 33 plants from a factorial survival and reproduction test about a week before, and 57 more plants of the same age and varieties. These plants were exposed in an outdoor cage to alates from heavily infested Honey Dew plants. A completely randomized design was used. The adults on each plant were counted after 3 days' exposure.

A week later 87 of the above plants were tested for apterous preference in the same cage. This test was as described for the other apterous test except that the plants were growing in 4 inch pots.

In the tests where the same plants were repeatedly used, aphids were removed after each test by exposing them to a dichlorvos impregnated strip in a closed chamber (Lowe and Russel 1969). The plants were aired for at least 3 days before they were reused. The performance of each plant was recorded so that the tests could be compared on a plant by plant basis. Diseased plants were discarded.

The field test was in the same manner as the preceding ones except that there were 8 replications. Analysis of the field test was by sign test because this analysis was suitable for multiple comparisons involving missing treatments in a completely randomized block design.

The C. sativus alate preference test was in the same manner as the C. melo alate preference except that plants were in 1½ x 1½ inch square

pots spaced on 4 inch centers and available alates were not as numerous.

Results and Discussion

Sixty varieties of Cucumis involving 13 species were included in the first 2 screenings. Twelve varieties were significantly more resistant (3% level) than the rest of the varieties screened. These included C. anguria PI 147065, C. fecifolius PI 196844 and 233646, C. metuliferus PI 202681 and PI 292190, and C. sativus PI 288330 in the first screening (Table 10) and C. anguria PI 196477 and PI 320052, C. africans PI 203974, C. dipsaceus PI 193498 and PI 236468, and C. sp. 164795 (interfertile with C. sativus) in the second screening (Table 11). Leppik (1968) reported PI 193498, PI 196844, PI 202681, and PI 233646 as tolerant and PI 147065 and PI 196477 as resistant to "greenhouse aphids". 'Snake Gourd' turned out to be Trichosanthes sp. and was resistant (Table 10).

In the screening of 7 C. melo varieties, PI 164320 was significantly resistant (3% level) (Table 12). PI 175111, from which Kishaba, Bohn, and Toba (1971) selected LJ 90234 as a single resistant plant, was not resistant as unselected material. PI 124112 showed moderate resistance in their test, but was about average in this screening (Table 12). Leppik (1968) reported PI 164320 as resistant in the text of his paper but as highly susceptible in his table.

Leppik (1966) found a number of gene centers of Cucumis, including one in the Arabian region of northern Africa, based on the numbers of varieties found in these regions that were resistant either to insects or plant diseases. There were no significant differences between the varietal means and variability of the 3 regions in the Cucumis screenings (Tables 10 and 11). Combining the data from both tables as

Table 10. Cucumis screening I. Number of aphids on individual plants 5 days after infestation with 3 apterae. Sign of deviation from replication median indicated by + or - following each count.^a

Variety	Origin	Replication					\bar{X}
		I	II	III	IV	V	
<u>C. africans</u>							
PI 274036	S. Africa	1-	3m	2-	6+	9m	4.2
<u>C. anguria</u>							
PI 147065	Brazil	0-	0-	0-	0-	0-r	0
<u>C. ficifolius</u>							
PI 196844	Ethiopia	0-	0-	0-	0-	0-r	0
PI 233646	Ethiopia	0-	0-	0-	0-	0-r	0
<u>C. melo</u>							
PI 193495	Ethiopia	17+	15+	24+	1-	46+	20.6
PI 222138	Afghanistan	9-	1-	24+	7+	23+	12.8
PI 224769	Korea	15+	24+	22+	22+	26+s	21.8
PI 224770	Africa	16+	20+	0-	0-	1-	7.4
Honey Dew	USA	67+	16+	66+	30+	0-	35.8
Spanish Melon	El Salvador	22+	23+	21+	32+	37+s	27.0
<u>C. membranifolius</u>							
PI 273650	Ethiopia	0-	3m	4-	3m	10+	4.0
<u>C. metuliferus</u>							
PI 202681	S. Africa	0-	0-	0-	0-	0-r	0
PI 292190	Transvaal	0-	2-	1-	1-	1-r	1.0
<u>C. myriocarpus</u>							
PI 282449	S. Africa	4-	21+	3-	7+	1-	7.2

Table 10. Continued

Variety	Origin	Replication					\bar{X}
		I	II	III	IV	V	
<u>C. sativus</u>							
PI 253500	Pakistan	28+	32+	27+	0-	29+	23.2
PI 275633	India	0-	56+	7-	1-	0-	12.8
PI 288330	India	0-	0-	0-	0-	0-r	0
PI 288331	India	58+	2-	4-	0-	21+	17.0
PI 323316	India	74+	0-	27+	70+	1-	34.4
Straight 8	USA	47+	11+	27+	54+	31+s	34.0
White Wonder	USA	10-	19+	64+	23+	2-	23.6
<u>C. zeyheri</u>							
PI 282450	S. Africa	2-	21+	1-	5+	11+	8.0
PI 299569	S. Africa	8-	13+	9m	0-	26+	11.2
PI 299570	Natal	17+	14+	48+	48+	14+s	28.2
PI 299571	S. Africa	11	2-	25+	4+	8-	10.0
PI 299572	S. Africa	30+	16+	12+	33+	17+s	21.6
<u>C. sp.</u>							
PI 122847	India	1-	2-	21+	4+	6-	6.8
PI 200816	Burma	13+	12+	30+	1-	13+	13.8
PI 200817	Burma	23+	3m	8-	1-	2-	7.4
PI 203978	S. Africa	0-	0-	36+	1-	0-	7.4
PI 212897	India	12+	8+	0-	21+	22+	12.6
PI 314427	USSR	32+	0-	9m	36+	9m	17.2
PI 314653	USSR	11	0-	31+	0-	13+	11.0
Median		11	3	9	3	9	
<u>Trichosanthes sp.</u>							
Snake Gourd	USA	0-	0-	0-	0-	4-r	0.8

^a Varietal data followed by r have significantly less +'s at the 3% level or s have significantly more +'s at the 3% level. Individual counts followed by m are equal to the median.

Table 11. Cucumis screening II. Number of aphids on individual plants 8 days after infestation with 3 apterae. Sign of deviation from replication median indicated by + or - following each count.^a

Variety	Origin	Replication					\bar{X}
		I	II	III	IV	V	
<u>C. africans</u>							
PI 203974	S. Africa	0-	24-	4-	7-	6-r	8.2
PI 273192	S. Africa	22+	44+	61+	22+	7-	31.2
<u>C. anguria</u>							
PI 196477	Brazil	0-	0-	0-	0-	0-r	0
PI 282442	S. Africa	0-	12-	18+	36+	15+	16.2
PI 320052	Ethiopia	0-	0-	0-	0-	1-r	0.2
<u>C. dipsaceus</u>							
PI 193498	Ethiopia	0-	0-	0-	0-	0-r	0
PI 236468	Ethiopia	0-	0-	0-	0-	0-r	0
<u>C. fecifolius</u>							
PI 203975	S. Africa	0-	12-	22+	1-	20+	11.0
<u>C. leptodermus</u>							
PI 282447	S. Africa	3-	68+	23+	88+	0-	36.4
<u>C. longipes</u>							
PI 249894	Rhodesia	14+	11-	0-	0-	2-	5.4
<u>C. melo</u>							
PI 214050	India	5-	56+	17m	30+	12m	24.0
PI 229807	Africa	129+	57+	93+	0-	1-	56.0
PI 234607	S. Africa	50+	59+	7-	9-	38+	32.6
PI 282448	S. Africa	69+	55+	0-	21+	7-	30.4
Edisto	USA	8m	40+	23+	47+	26+s	28.8
Hales Best J.I.	USA	31+	21-	101+	47+	23+	44.6
Honey Dew	USA	29+	46+	41+	61+	57+s	46.8

Table 11. Continued

Variety	Origin	Replication					X
		I	II	III	IV	V	
<u>C. melo</u> (continued)							
Planters Jumbo	USA	84+	32+	100+	39+	40+s	59.0
Smiths Perfect	Isle of Pines	23+	57+	127+	42+	36+s	57.0
<u>C. prophetarum</u>							
PI 179922	India	1-	27m	0-	1-	12m	8.2
PI 273648	Ethiopia	2-	7-	17m	4-	0-	6.0
<u>C. sp.</u>							
PI 164327	India	9+	49+	34+	16m	24+	26.4
PI 164795	India	0-	0-	0-	0-	0-r	0
PI 203977	S. Africa	5-	15-	23-	4-	10-	0
PI 314654	USSR	19+	35+	13-	25+	85+	35.4
PI 319217	UAR	21+	99+	55+	60+	30+s	53.0
PI 319218	UAR	9+	14-	5-	42+	24+	18.8
Median		8	27	17	16	12	

^aVarietal data followed by r have significantly less +'s at the 3% level or s have significantly more +'s at the 3% level. Individual counts followed by m are equal to the median.

Table 12. Number of aphids on individual Cucumis melo plants 5 days after infestation with 3 apterae. Sign of deviation from median indicated by + or - following each count.^a

Variety	Origin	Replication				
		I	II	III	IV	V
Honey Dew	USA	55+	36+	40m	34-	7-
Hales Best J.I.	USA	24-		23-	41m	33+
PI 124112	India	36m	11m	25-	11-	9m
PI 164320	India	6-	0-	1-	1-	2-r
PI 175111	Turkey	50+		50+	56+	51+
PI 179671	India	49+	5-	60+	53+	0-
PI 314654	USSR	13-	11m	50+	48+	24+
Median		36	11	40	41	9

^aVarietal data followed by r have significantly less +'s at the 3% level. Individual counts followed by m are equal to the median.

independent samples still did not detect significance. In the screening shown in Table 11 the USA varieties had significantly (5% level) higher means than the Ethiopian and Arabian varieties. However, it was noted that USA had only C. melo in the screening whereas Ethiopia and Arabia had only C. anguria complex. A subsequent Dunn's (1964) test showed that C. melo had significantly (5% level) higher varietal means (Table 11) than did varieties in the C. anguria complex. Analysis of data from Table 10 showed significantly (5% level) higher varietal means for both C. melo and C. sativus when each was compared with the C. anguria complex. Perhaps Cucumis is too heterogeneous to consider as a group. The deliberate inclusion of all available species in the screening may have smoothed out regional differences which may be detectable when screening a single species. Analyzing the C. anguria complex alone, Ethiopian and Arabian introductions were significantly less susceptible (5% level) than southern Africa introductions in both the first and second screening. This lower regional susceptibility differs from Citrullus in which regions only differed in variability. Ethiopia and Arabia should be of interest to anyone seeking gerkins resistant to melon aphids.

In the test of C. melo and C. metuliferus, PI 164320 was significantly (5% level) more resistant than 4 of the cultivars with which it was compared (Table 13). 'Rocky Ford' produced more aphids than PI 164320 in 6 replicates, the other two being 0, but Rocky Ford was not statistically different in this test (Table 13). Smiths Perfect was significantly (5% level) more susceptible to aphid survival and multiplication than PI 164320. In the screening (Table 11) Smiths Perfect was significantly (3% level) more susceptible than the population median, despite reported

Table 13. Number of aphids on individual *Cucumis metuliferus* and *C. melo* plants 7 days after infestation with 3 apterous 5 to 6 day old aphids. C. melo analyzed by Friedman's test (Langley 1970).

Variety	Replication						\bar{x}
	I	II	III	IV	Va	VII	VIII
	<u>C. metuliferus</u>						
PI 202681	0	0	0	0	1	0	0
PI 292190	0	0	0	0	1	2	0
	<u>C. melo</u>						
PI 164320	0	0	0	1	0	0	0
Edisto 47	3	45	0	0	19	25	19
Hales Best	15	97	74	51	81	147	126
Honey Dew	102	128	51	125	143	54	64
Planters J.I.	98	78	53	104	81	53	6
Rocky Ford	9	55	27	71	64	0	30
Smiths Perfect	55	82	24	94		111	17
							32
							59.3*

^aColumn incomplete, not included in statistical analysis for Smiths Perfect.

^bRow incomplete, not included in statistical analysis of other varieties.

*Significantly different from PI 164320 at the 5% level.

**Significantly different from PI 164320 at the 1% level.

resistance by Ivanoff (1944, 1945). Several workers at the November 15, 1971 Cantaloupe Workshop held at the US Vegetable Breeding Laboratory, Charleston, North Carolina, reported aphid infestations of Smiths Perfect in the field and concluded commercial seed increases had lost the resistance. However, Kishaba, Bohn, and Toba (1971) working with related Cu6 and 'Texas No. 1' from experiment station stocks concluded that their melon aphids were another biotype. The type of resistance with which Ivanoff worked may be geographically very limited in usefulness. His varieties came from stock originally from the West Indies where melon aphid is a severe problem (Wolcott 1927, 1955). It would be interesting to know if these varieties, resistant in parts of the southeastern US, but not resistant in several other regions, including Florida, are resistant in the West Indies where they originated. Although C. metuliferus PI 202681 and PI 292190 were included in the test, they were not statistically compared with C. melo varieties (Table 12). Their performance was about the same as that of PI 164320. They were also resistant when screened (Table 10). Norton (1969) reported crossing PI 202681 with C. melo and obtaining several fertile backcross generations. Perhaps aphid resistance can be transferred from C. metuliferus to C. melo by similar introgressive hybridization.

The accidental infestation in a small cage where aphids had free access to 2 varieties produced aphid numbers ranging from none to more than a hundred per plant. PI 164320 was significantly (1% level) resistant in comparison with Honey Dew (Table 14). These plants were returned to their original locations and 7 days later about 1/2 were dead. One (lowest ranking) Honey Dew plant had been removed during this period and only one other of this variety survived. The difference between the survival of

Table 14. Seedlings of Cucumis melo, PI 164320 and Honey Dew grown in a completely randomized pattern and accidentally infested with Aphis gossypii, ranked from least infested (1) to most infested (24).

	Variety	
	PI 164320	Honey Dew
	1.5 ^a	6
	1.5 ^a	9
	3	14
	4	16
	5	17
	7	18
	8	19
	10	20
	11	21
	12	22
	13	23
	15	24
Total	91**	209

^aPositions 1 and 2 were tied in that no aphids were present.

**Significant by Wilcoxon's sum of ranks test at the 1% level.

the varieties by a chi-square test was significant (5% level) even assuming both Honey Dew plants would have survived. Because of lack of a control, it is not certain that the difference is entirely due to the difference in tolerance to melon aphid of the 2 varieties.

In the first preference test (Table 15) LJ 90234 was significantly more resistant (5% level based on 4 plants) than the C. melo population tested. The mean of PI 164320 was less than any of the remaining varieties. The preceding test used apterae because they had been used in all previous tests, but colonization is most frequently initiated by alates. In a 90 plant C. melo alate preference test (Table 16) 4 other varieties including Rocky Ford were significantly (1% level) preferred to PI 164320. Nymphs were found on every plant except 1 PI 164320 (that had no alates). This shows that all the other plants had at least alates on them once during the test period. A subsequent apterous preference test using 87 of the original 90 plants found the same varieties significantly (1% level) preferred over PI 164320 (Table 17).

The weather had been wet prior to the Cucumis field test and a tropical storm developed in the area during the test. The aphids did not do well with the heavy rains and several hills of plants were lost to downy mildew. Still, the number of aphids on Honey Dew and PMR 45 increased and PMR 45 was significantly more susceptible (3% level) than PI 164320 (Table 18). PI 164320 was significantly more resistant than the population mean (1% level). LJ 90234 was more resistant than the population mean (1% level). LJ 90234 was more resistant than PMR 45 (3% level) and may have been similar to PI 164320 in resistance. LJ 90234 appears to be resistant to melon aphids in Florida both on the basis of the preference test (Table 15) and the field test. This variety was selected for

Table 15. Number of apterae per plant 3 days after each plant was infested with 5 adult apterae and all were placed together in a small cage.

Variety	Number of apterae															No. Zeros	\bar{X}
LJ 90234	0	0	0	0												4*	0
PI 164320	0	0	2	0	0	1	1	0	0	0						7	0.40
Honey Dew	3	2	2	3	3	4	1	2	8	2	4	3	4	2	3	0	3.07
PMR 45	3	2	2	2	3	4										0	2.67
Rocky Ford	1	3	5	2	4	1	3	3	4	6	0	1	3	4	3	1	2.87

*Significantly more 0's than expected on the basis of the combined data at the 5% level.

Table 16. Number of alates on individual plants of Cucumis melo after 3 days' exposure to heavily infested Honey Dew plants.

Variety	Number of alates																		\bar{X}
	8	7	2	10	3	1	3	13	8	13	9	10	11	27	15	7	2	11	
PI 124112	8	7	2	10	3	1	3	13	8	13	9	10	11	27	15	7	2	11	8.89**
PI 164320	2	1	1	3	0	0	1	1	3	0	2	5	0	3	2	0	2	14	2.21
PI 179671	3	28	1	10	2	5	3	5	1	10	23	14	15	9	20	8	32	4	10.72**
Hales Best J.I.	6	7	12	1	3	7	26	5	6	12	17	13	12	13	8	3	26	13	10.56**
Rocky Ford	17	18	12	8	11	4	9	22	7	7	14	7	25	18	26	9	3		12.76**

**Significantly different from PI 164330 at the 1% level.

Table 17. Number of apterae on individual *Cucumis melo* plants 3 days after infestation with 5 apterae. Plants taken from alate test (Table 16).

Variety	Number of apterae															\bar{X}
PI 124112	7	2	2	2	4	4	5	3	3	1	5	3	2	1	1	3.00**
PI 164320	1	0	1	2	2	1	1	3	0	1	0	1	0	1	0	1.18
PI 179671	6	0	2	2	4	3	2	2	5	7	2	0	3	1	2	2.60**
Hales Best J.I.	3	5	7	2	2	6	3	9	2	0	5	5	6	7	0	4.50***
Rocky Ford	4	0	5	8	9	3	6	5	11	14	1	5	6	3	1	5.06**

**Significantly different from PI 164320 at the 1% level.

***Significantly different from PI 164320 at the 0.2% level.

Table 18. Number of aphids 5 days after infestation with 3 apterae placed on the tip of a Cucumis runner and covered by an organdy bag in the field. 1972.

Variety (v)	Block (b)								\bar{X}_v	V_s \bar{x}_b^a
	I	II	III	IV	V	VI	VII	VIII		
	6/18 -6/23	6/23 -6/28	6/28 -7/3	6/28 -7/3	6/28 -7/3	6/28 -7/3	6/26 -7/1	6/26 -7/1		
PI 147065	0	0	0	0	0	0			0	0.031
	<u>C. anguria</u>									
PI 164320	0	0	0	0	0		0	0	0 ^r	.008
LJ 90234	1	3	0	0	1		1	1	1.0 ^r	
Honey Dew	39	4	1		0		2		9.2	
PMR 45	6	9	3	1	20	0		1	5.7	
	<u>C. sativus</u>									
PI 288331	1	0	0	0	0	0	4	0	0.6	.062
PI 164795 ^x	0	1	0	5					1.5	
PI 288330	1	0	1		0		5	0	1.1	
\bar{x}_b	6	2.1	0.6	1	3.4	0	2.4	0.4		

^aNumbers are probabilities that the difference is by chance alone.

^rResistant compared to PMR 45 at the 3% level.

^xCucumis sp. interfertile with C. sativus.

resistance to California melon aphids and its performance in both areas gives hope for the development of varieties resistant to melon aphid over geographically broad areas.

C. anguria PI 282442 was deleted from analysis and Table 18 because it had a virus infection in every replication. The virus was tentatively diagnosed as watermelon mosaic virus by Dr. D. Purcifall. One plant of C. anguria PI 147065 also showed virus symptoms and that hill was also deleted from consideration. However, had PI 282442 been included in the analysis it would have approached significance (6% level) as more susceptible to melon aphid than PI 147065. PI 147065 was resistant (3% level) in the field test compared to the population mean (Table 11) and was also resistant (3% level) in the screening (Table 10). PI 282442 was significantly more resistant (3% level) than the population with which it had been screened (Table 11).

C. sativus PI 288331 and related PI 164795, both resistant when screened, were not significantly resistant in the field even though the average number of aphids on each decreased during the test. PI 288331 which was not notably resistant in the screening was nearly (6% level) significantly more resistant than the population screened. The variability of PI 288331 in the screening may have been due to the packet containing a mixture of resistant and susceptible seeds perhaps from an accidental outcross in a preceding generation. If so, the plant used to increase this seed (by selfing) may have given rise to all resistant progeny used in the field test. In either case, it is possible that all 3 introductions in the C. sativus part of the field test may have been resistant. However, an alate preference test (Table 19) failed to show any significance between these 3 introductions or between any of them and US cultivars

Table 19. Number of alates on individual Cucumis sativus plants after 3 days' exposure to heavily infested Honey Dew plants.

Variety	Number of alates											\bar{X}^*
PI 164795	2	1	1	2	3	2	9					2.86
PI 288330	2	1	0	0	1	3	3	3	3	0		1.60
PI 288331	2	6	0	1	2	6	2	1	0	2	1	2.09
Straight 8	1	10	4	1	2	6	1	2	7	3	3	3.64
White Wonder	4	0	1	3	1	1	10	2	1	0	3	2.36

*No significance was found.

'White Wonder' and 'Straight 8'. The latter had the highest average number of aphids.

Two regions of interest to plant introduction explorers were noted. One type, that of Vavilov (1951) and Harlan (1961), was noted for Citrullus in Africa. This type of region is characterized by variability resulting perhaps from occasional germ plasm exchange between 2 or more populations (races or subspecies) undergoing different types of selection. Another is an area in which the population on the average seems to be more resistant than elsewhere. Such an area might occur if the pest under consideration is a severe selective factor in a region or if some other selective factor in the region incidentally selects for resistance to the pest under consideration. Ethiopia and Arabia may be such an area for melon aphid resistance in the Cucumis anguria complex. This type of gene center may have been to some extent neglected by plant breeders who depend on variability (including a good deal of heterozygosity) to make gains in such quantitatively inherited characters as yield.

GENETICS AND BIOLOGY

Knowledge of how resistance is inherited is essential for application in plant breeding programs. Because the resistance to melon aphid was so marked in Cucumis melo PI 164320 it received the bulk of the attention in biology and genetics experiments.

Materials and Methods

The preliminary Cucumis melo genetic study involved a cross between a resistant variety PI 164320 and the susceptible variety Honey Dew. The procedure was as in the C. melo and C. metuliferus test, but it consisted of 24 randomized complete blocks and ran 7 days. Each block contained 4 entries; self of PI 164320 maternal parent; Honey Dew from the same batch of seed as the pollen parent; F_1 and F_2 . The results for the parents and F_1 were analyzed by Friedman's test and its multiple comparison extension (Langley 1970) to compare the resistance of the nonsegregating generations. Each F_2 plant was then designated resistant or susceptible by comparing the number of aphids on it with the numbers on F_1 and parental entries. The number of F_2 plants in each designation was then compared with Mendelian ratios using Warwick's (1932) table based on exact binomial probabilities. About a week later 4 blocks of parent and F_1 plants from the above test were retested in the greenhouse to confirm the relationship of the nonsegregating generations in a different environment. Analysis was the same as for the above nonsegregating generations. During the first test records were kept for the first

4 days of the number of nymphs and adults on the leaves and on the cotyledons of each plant. Thereafter total numbers were recorded daily for leaves and cotyledons. Spearman's correlation was used to compare the two tests using data from plants included in both tests (Langley 1970).

The final Cucumis melo genetic test used a cross of PI 164320 (resistant) and PI 314654 (susceptible). The latter was introduced as Cucumis sp., but was interfertile with and for all practical purposes was cospecific with Cucumis melo. Entries included selfs of the maternal PI 164320 and pollen PI 314654 plants, their F_1 and F_2 progeny, and backcrosses of an F_1 to selfs of each parent. The procedure was as in the first test except that a completely randomized design was used.

The factorial test (previously mentioned) from which came 33 plants of the 90 used in the large C. melo preference test involved 5 varieties tested under 4 conditions, in hopes of better understanding the variability observed within lines throughout the study. The conditions established involved 2 temperature regimes each lasting for 5 and 7 days. The 7 day test began 1 day before the 5 day test and ended 1 day after it. One temperature regime was 29° C during the light period and 26° C during the dark period and the other 27° C during the light period, 24° C during the dark. Two plants were grown, infested and covered for each measurement in the same way as for the C. melo and C. metuliferus test. Friedman's test was used to test varieties as a factor with conditions as replications and then conditions were used as a factor and varieties as replications (Conover 1971). The multiple range extension of Friedman's test was used to separate subunits of significant factors (Langley 1970). Interaction was not examined. Five and 7 day varietal

data were used as 10 replications to compare temperature regimes by Wilcoxon's signed ranks test and then varietal data for the 2 temperature regimes were used to compare 5 and 7 days (Langley 1970). Spearman's correlation test was applied to the data resulting from the inclusion of the same plants in both this, the second apterous preference, and alate test. It was also applied to other cases in which plants were used in more than one test (Langley 1970). In some instances the correlations involved several independent samples (or strata). In these cases the Z values of Spearman's test were squared, signed, and summed as chi-square estimates of significance.

The effects of plant age and source of aphids was investigated using 9 plants, each of PI 164320 (resistant) and Honey Dew (susceptible) for each treatment. Controls consisted of month (from planting) old plants infested with apterae reared on Hales Best J.I. Plants. The "young" treatment consisted of plants planted 20 days later that were in the early first leaf stage. Another treatment consisted of aphids reared on Blue Hubbard, "squash", plants. Plants were grown, covered and tested under the conditions described for the Citrullus screening. After 3 days the number of nymphs and adults on each plant was recorded and analyzed using the Kruskal and Wallis test and its multiple range extension (Langley 1970).

Results and Discussion

PI 164320 and F_1 were both significantly more resistant (1% level) than Honey Dew in the preliminary genetic test but were very similar in aphid survival and reproduction (Table 20). None of the PI 164320 and F_1 plants had more than 10 aphids at the end of the test whereas

Table 20. Number of aphids on individual plants, in the first Cucumis melo genetics test, 5 days after infestation with 3 apterae.^a

Replication ^a	PI 164320	Honey Dew	F ₁	F ₂
I	4	49	0	2r
II	6	90	0	4r
III	0	39	1	1r
IV	3	28	1	51s
V	0	127	3	53s
VI	0	72	0	126s
VII	1	19	1	0r
VIII	0	12	1	6r
IX	7	59	10	15s
X	3	19	0	90s
XI	0	66	0	0r
XII	1	3 ^x	0	4r
XIII	0	49	1	1r
XIV	6	69	0	7r
XV	10	122	2	13s
XVI	1	6 ^x	1	5r
XVII	0	26	0	0r
XVIII	1	145	1	9r
XIX	3	120	1	2r
XX	3	93	3	1r
XXI	7	70	0	47s
XXII	0	68	2	17s
XXIII	6	90	2	9r
XXIV	0	158	3	101s

^aPhenotypes followed by r = F₂ counted as resistant or s = F₂ counted as susceptible.

^xAtypical phenotypic expression.

Honey Dew only had 2 that had less than 10. Therefore it was decided to count the F_2 plants with more than 10 aphids and add 0.1 times that number to it as an approximation of the number of plants that were genotypically susceptible. This number was subtracted from the total number of plants to approximate the number of genotypically resistant plants. The resultant 14 resistant to 10 susceptible has a 16% chance of deviating this much by chance alone assuming the Mendelian ratio, based on a very large population, to be 9:7 resistant to susceptible. This would be possible if 2 dominant alleles were necessary for resistance. Unfortunately the complete block design constitutes over randomization in conjunction with this type of analysis and could (however unlikely) theoretically introduce bias.

The resistance relationship between both parents and the F_1 was the same in the greenhouse as in the rearing room. Total aphid counts on plants included in both this and the preliminary C. melo genetic test were significant (1% level) for direct correlation between the two tests.

The final C. melo genetic test using a more appropriate completely randomized design also had a fairly good fit (52 resistant:34 susceptible) to the above model (chi-square = 1.7) based on the F_2 (Table 21). The backcross to resistant PI 164320 produced all resistant phenotypes as did the F_1 ; these results were also consistent with the model. The backcross to the susceptible was expected to produce a ratio 1:3 resistant to susceptible PI 314654 and a ratio of 18:7 was observed. The probability of the ratio deviating this much by chance alone is less than 1 in 1000. This particular cross was particularly convenient in that no overlap between aphid counts for resistant and susceptible plants

Table 21. Number of aphids on individual plants in the Cucumis melo genetics test 5 days after infestation with 3 apterae.^a

Variety	Number of Aphids													
Self of PI 164320	0	1	0	0	0	0	0	1	0	0	0	0	9	0
	0	0	(all resistant)											
Self of PI 314645	37	35	33	19	20	29	58	19	15	(all susceptible)				
F ₁ PI 314654 x 164320	0	0	1	0	0	0	0	1	0	2	0	2	0	9
	1	0	0	0	0	0	2	0	2	0	2	0	0	0
F ₂ (Self of F ₁)	Or	Or	33s	35s	72s	51s	45s	97s	8r	Or	1r	1r	68s	
	2r	Or	25s	Or	1r	11s	Or	Or	46s	or	Or	Or	60s	12s
	58s	60s	Or	Or	Or	Or	Or	Or	5r	37s	133s	25s	107s	
	49s	18s	Or	1r	2r	1r	29s	Or	Or	Or	5r	64s	Or	Or
	1r	39s	89s	37s	1r	10s	Or	1r	24s	7r	Or	21s	64s	Or
	Or	9r	1r	62s	1r	Or	Or	Or	Or	10s	2r	46s	Or	Or
	2r	Or	4r	Or	33s	41s	Or	Or						
BR (F ₁ X Self PI 164320)	0	0	0	2	0	0	1	0	0	2	0	1		
	1	5	0	0	0	3	(all resistant)							
BS (F ₁ X Self PI 314654)	Or	Or	Or	Or	55s	Or	23s	Or	1r	Or	Or	18s	Or	
	Or	3r	10s	Or	75s	1r	Or	27s	130s	1r	Or	9r		

^a Individual counts followed by r counted as susceptible, and by s counted as resistant.

occurred. Inheritance appeared simple in both genetic tests, yet it was not possible to fit the data to simple Mendelian models involving 1, 2 or 3 genes. Maternal effects did not appear using PI 164320 as the F_1 maternal parent in the first test and the pollen parent in the second test.

The factorial test of 5 varieties tested under 4 conditions showed significant (5% level) differences between PI 164320 and Rocky Ford and Hales Best J.I. The mean of PI 164320 was, again, lower than that of any other entry (Table 22). None of the conditions (as factors) were significantly different from each other. The 2 temperatures and even the number of days elapsed during the test were nonsignificant. Although this test was unable to detect differences between PI 164320 and 2 of 4 varieties already known susceptible some varietal differences were found but no differences between temperature or temporal differences. This suggests that the effect of these variables was not as great as that of the observed resistance of PI 164320. Neither the second apterous preference test nor the alate test was correlated with survival and reproduction in the factorial test when tested on a plant per plant basis. The inclusion of varieties known to be preferred (Honey Dew) and non-preferred (PI 164320) in the sample actually biases the test towards direct correlation. Recalculation of the correlation with varieties as separate samples was also nonsignificant. The lack of correlation may be associated with aphids choosing plants on the some basis not directly related to immediate survival and reproduction, except in the case of marked varietal resistance. The 87 paired measurements resulting from the inclusion of the same plants in alate and apterous tests were not statistically correlated using either varieties as independent samples

Table 22. Number of aphids per 2 Cucumis melo plants, 5 varieties under 4 conditions. Totals summed for each variety under each condition as replications for varieties, and varieties as replications for conditions. Started with 3 apterae per plant.

Variety	5 day		7 day		\bar{x}_r
	27°C	29°C	27°C	29°C	
PI 164320	70	11	13	10	26.00
Rocky Ford	215	210	36	90	137.8*
PI 124112	140	153	44	65	100.5
PI 179671	47	36	229	57	92.25
Hales Best J.I.	215	289	136	81	180.2*
\bar{x}_c	137.4	139.8	91.60	60.60	

*Significantly different from PI 164320 at the 5% level.

or with all the data combined. The possibility remains that apterae and alates did not choose plants by the same criteria. The previously mentioned significance of survival and reproduction in the rearing room correlated with survival and reproduction as parents and F_1 in the greenhouse suggest that the test is not insensitive. However, even correlation proves little, and lack of it perhaps means less.

Neither plant age nor source of aphids significantly affected the resistance of PI 164320 or the susceptibility of Honey Dew (Table 23).

In various tests it was noted that a larger portion of the aphids on PI 164320 were moving at the time of observation than on other varieties. Aphids from PI 164320 were also more frequently found on the sides of chimneys and on the soil in the screening and subsequent tests involving colonization and reproduction. It was also noted that if laboratory plants were given insufficient light, presumably starving the aphids, the aphids were rather inactive until the plant was definitely wilted and dying. The aphids would then be found moving around on the plant as observed in PI 164320, although involving a still larger proportion of the aphids. These observations lead me to suspect either a feeding stimulant is not as concentrated in PI 164320 or that a repellent is present. The 3 Cucumis melo preference tests also suggest that the mode of action of this resistance involves preference (Tables 6, 7, and 8). Nonpreference may be an effective barrier to aphid survival and reproduction as it interferes with aphids receiving sufficient nutrition. Perhaps aphids wandering off nonpreferred plants perish before finding their way back. Kennedy and Booth (1951) said readiness to settle down for a long period and reproduction rate vary together. Reinhard (1927) concluded that alate production resulted from starving of the mothers.

Table 23. Number of aphids on individual Cucumis melo plants 3 days after infestation with 3 apterae, using 2 sources of aphids and plants of 2 ages.

Aphids Reared on Hales Best J.I.				Aphids Reared on Squash		
Young Plants						
PI 164320	Honey Dew	PI 164320	Honey Dew	PI 164320	Honey Dew	
2	5	2	8	7	25	
2	16	3	26	0	18	
8	12	0	8	8	23	
2	18	3	24	2	9	
4	12	0	21	2	19	
3	23	2	4	3	21	
0	31	4	19	0	12	
1	4	0	10	0	3	
5	14	1	21	7	5	
8	7	1	14	5	6	
X*	3.5a	14.2b	1.6a	15.5b	3.4a	14.1b

*Means followed by the same letter are not significantly different at the 5% level.

However, his technique involved removing the aphids for a starvation period each day and the disturbance may have been a major factor in itself. Presumably alate production would result from the decreased food uptake associated with nonpreference, but there did not seem to be more alates on resistant PI 164320 plants than were observed on susceptible plants at the same level of infestation.

Kishaba, Bohn, and Toba (1971) pointed out that care must be taken in breeding programs to prevent introduction of susceptibility to one pest while resistance to another is being developed. PI 164320 was very heavily infested by twospotted mites in the greenhouse while infestations were still light on nearby plants of other varieties. Perhaps PI 164320 is highly susceptible to twospotted mites. This possibility should be tested under more controlled conditions. Mites did not appear to be a problem in the field. It would be interesting to test PI 164320 for resistance to spotted cucumber beetle because resistance to it might be associated with susceptibility to twospotted mites (Da Costa and Jones 1971, Chambliss and Jones 1966).

The resistance observed in the case of PI 164320 seems to be qualitatively inherited, and is perhaps dependent on an extra metabolic step or a metabolic block. If such resistance is analogous to presence or absence of an insecticide it may be relatively simple for insect populations to be selected to overcome such a barrier (Gordin 1961). Possibly continuously inherited (inherited via more genes than can be distinguished individually) forms of resistance may include several mechanisms or barriers. The chance of a population overcoming additional coexisting factors decreases geometrically as additional factors are added. The Citrullus screening does not show any sharp demarcations

indicative of simply inherited resistance (Table 1). Perhaps the resistance observed in Citrullus PI 296335 and PI 299563 is continuously inherited, but that remains to be proven. Perhaps there are qualitative resistant strains of Citrullus homologous to those in Cucumis, or perhaps those discovered are homologous and merely failed to stand out sharply because the population screened was so variable. Obviously genetic work needs to be done on Citrullus.

In many of the tests presented in this and the preceding chapter it was mentioned that data were taken concerning nymph and adult numbers and whether they occurred on leaves or cotyledons. The data concerning aphid age failed to reveal any consistent trend related to resistance or its mode of action. In the first Cucumis screening Snake Gourd, Trichosanthes sp., appeared to support aphid survival and reproduction on the cotyledons while the leaves were highly resistant. This was also observed in several less formal situations, but no such relation existed for any other genus or variety tested. Aphids did as well on the cotyledons of susceptible plants as on the leaves, migrating to the leaves as the cotyledons became very senescent. Resistant plants seemed to be resistant regardless of the plant part. Perhaps the resistance of Snake Gourd vegetation to melon aphid is a result of a completely different mechanism of melon aphid resistance than was observed in other plants investigated. Most cucurbits belong to homologous series, that is leaf shapes found in cantaloupes also occur in squashes and watermelons, etc. Perhaps the homolog of Trichosanthes resistance remains to be found in more useful cucurbits.

I hope that the germ plasm and gene centers uncovered in this study will lead to the eventual development of melon aphid resistant cultivars for Florida and other regions.

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Lewis Earl MacCarter was born October 1, 1940, at Ross, California. He graduated from Newport Harbor High School, Newport Beach, California, in 1959. He studied biology at Orange Coast College and zoology at San Diego State College before enrolling at the University of Florida where he received his Bachelor of Science in Agriculture in 1963.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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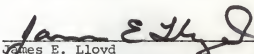
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